**Buoyancy exercise**

Objective: Students will be able to use the concept of buoyancy to explain how magmas rise.

Causal Principle used in this exercise:

1. **Temperature** is a measure of the movement of molecules. Higher temperature means molecules are moving faster.
2. When molecules move faster, the **density** of most substances decreases. Water is an anomaly because liquid water is more dense than ice.
3. **Buoyancy** causes materials to rise or fall due to the relative density of materials.

*The Albuquerque Balloon Festival.*

*I left home before sunrise to watch the morning ascent. More than 500 air balloons would be rising in a spectacle that I had never witnessed. Unfortunately, lots of others had the same idea so I missed lift off of the first balloons but I could see them glowing in the distance like flickering bubbles in the sky. Each balloon would light up for a few minutes when the pilot turned up the flame that heats the air in the balloon. The flame would light up the balloon until the pilot had created enough lift. Then that balloon would fade into darkness as another lit up.*

*There were hundreds of balloons in the air by the time I got to the launching area but others on the ground were just being laid out. The pilot and others working with him would lay out the balloon then use giant fans to begin to inflate them. Inflated with air forced by the fans, the balloons laid on the ground until someone lit the gas flame that slowly heated the air in the balloon. The hot air caused the balloon to grow larger and eventually rise. Crew members tethered the balloon to the ground while it inflated. Once the balloon was full inflated, the pilot and two crew members entered the gondola, other crew members released the ropes and the balloon slowly rose and headed south with the cool morning breeze.*

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*http://www.balloonfiesta.com/uploads/images/photo-contest/2010/94.jpg*

*The first balloons up were the standard balloon shape. Others were still inflating more elaborate balloons. One looked like Darth Vader’s head. Another was shaped like a castle. These irregularly shaped balloons were more difficult to launch and a few never made it off the ground.*

*The sun was fully up before the last lift-off. Balloons of all shapes were having difficulty rising as the bright morning sun warmed the air. The balloons that had left the launch area before dawn had drifted southward for a few tens of miles. Balloons quickly lose heat to the surrounding cooler air so pilots have to re-ignite the gas flames to warm the air in the balloon. One pilot continued to heat the air in her balloon until it rose 4000 feet above the ground. It was pretty cold at that elevation but she had dressed warmly and was enjoying the view of the Rio Grande River below when she noticed that her gas tank was low on fuel. Had a crew member forgotten to check the tank? Had she used up too much fuel in her ascent? Regardless, she needed to begin her decent quickly while she still had enough fuel to guide her descent. Below her were the many balloonist’s hazards presented by a big city.*

*Ballooning is not without hazard. Strong winds can cause a pilot to stray off course. Lightening can be deadly. But his day, everyone landed safely.*

*None of the pilots flew very high. The world record height for a hot air balloon is about thirteen miles. At that elevation, the density of the atmosphere is so low that heating the air molecules cannot over come the weight of the balloon and all the equipment, such as oxygen, the pilot needs to survive.*

*The Ring of Fire*

*The diagram below shows the Ring of Fire, a zone of volcanic activity that surrounds much of the Pacific Ocean.*

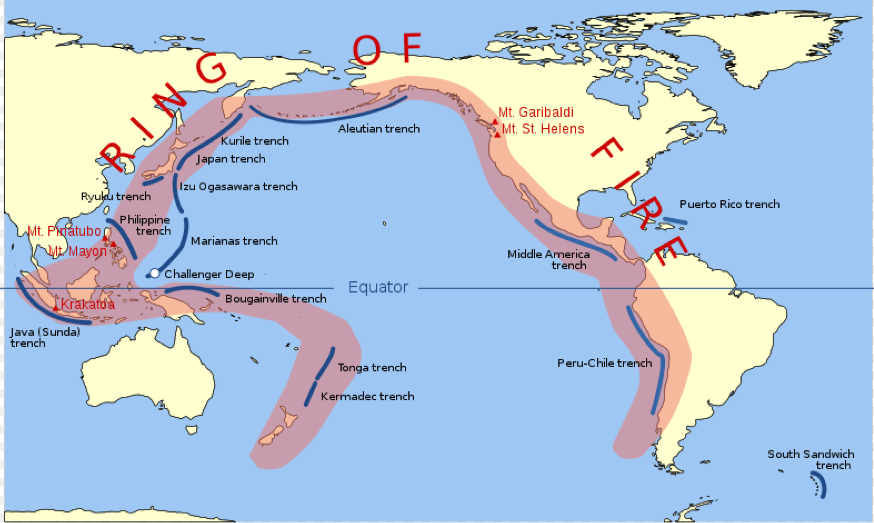
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Figure 1. The Ring of Fire (from Wikipedia)

*Geologists wondered about the origin of the volcanoes that make up the Ring of Fire long before Plate Tectonic theory and a better understanding of causes of mantle melting were understood*. *Today we recognize the Ring of Fire as roughly parallel to subductions zones where oceanic lithosphere sinks beneath either continental lithosphere or other, less dense oceanic lithosphere. The sinking oceanic lithosphere releases water into the overlying mantle and this water causes the mantle to melt. Geologists used to think melting of the mantle was caused by somehow raising its temperature. Today, we realize that adding water to hot, dry rocks can cause them to melt and there is good evidence that this is what forms many of the magmas that erupt from the Ring of Fire volcanoes.*

*When rocks melt, the magma is less dense than the rock from which is was derived. Therefore, the magma may begin to rise. Many of the magmas that form at subduction zones are 50- 100 kilometers below the surface so they’ve a long way to go before they erupt. Some of them never make it all the way up. As they rise, they slowly cool. If the lithosphere through which they are rising is cool enough, the magma itself may cool. As the magmas cool, they become denser and this can slow their ascent. Some magmas cool enough to crystallize within the crust. Large masses of cooled magma form igneous rocks that are the core of many mountains.*

*When magmas cool, heat is transferred from the magma to the surrounding crust. This heats the crust. One magma follows another like a train of rising bubbles, each adding heat to the surrounding crust. Because the magma gets hooter, each magma cools a bit less than the former magma and eventually they may rise to the surface where they spew forth as volcanic eruptions.*

*One of the truly remarkable things about the rise of magma in the lithosphere is that the lithosphere is solid. Is it possible for magma to rise through solid rock? One might imagine deep fractures that serve as conduits for the magma but fractures in rocks deeper than 10 -15 miles below the surface can not remain open. The pressures are too great. And rocks at high temperature can flow sort of like warm wax. As magma rise and heat the lithosphere, the lithosphere becomes less rigid so it flows more readily. This too contributes to the rising of magma.*

*The upper few miles of the continental crust is cooler and, as a result, more brittle than the lower crust and mantle. Magmas in the upper crust may rise along fractures. These fractures provide pathways alongh which magma may rise but these long narrow pathways also may change the shape of the mamga from a round form to a narrow sheet. A narrow sheet of mgma will lose cool much more rapidly than a round plume. Therefore, many magmas cool and solidify within fractures in the upper crust.*

*You may recall that continental lithosphere is composed of rocks that are less dense than oceanic lithosphere. Therefore, when magmas intrude continental lithosphere, the encounter less dense surroundings and this too can slow or halt their ascent.*

*One more process contributes to the rise of magmas. As magma rises, gases dissolved in the magma are released as the magma rises because the pressure of the overlying material becomes less. This is like removing the cap from a bottle of coke. When the cap is released, gas bubbles form due to the release of pressure and begin to rise through the liquid. Sometimes the gas is release violently enough that it pushes some of the coke out of the bottle. In a similar manner, gas may be releases from magma and these gas bubbles make the magma less dense, helping it rise. Water and carbon dioxide are two of the most common gases in magmas. These are released to the atmosphere when magmas erupt. In many cases, gases slowly leak out of a magma before it erupts. This causes the magma to become more dense and it may sink through the underlying magma. This rising or gas-oich magma and sinking of gas depleted magma looks very much like the rising and falling of fluid in a lava lamp.*

**Part A. Feature and Factors affecting the rising and falling of balloons**

Table1 lists a variety of elements of the description above of hot air balloons. For each element listed, decribe that element’s role in causing or effecting the balloon’s motion. The first two rows have been complete as examples.

Table 1

|  |  |
| --- | --- |
| **Elements** | **Causes and effects on balloon motion** |
| Gas flame | *Causes density decrease* |
| Limited fuel to continue heating the air in the balloon | *Slows or limits height of ascent* |
| Atmosphere surrounding balloon | *More dense than balloon* |
| Atmosphere decreases in density with increased elevation | *Slows the ascent of balloon* |
| Air get warmer during the day | *Decreases density contrast which decreases buoyancy* |
| When the balloon stops being heated it descends | *Increased density due to cooling* |
| Irregular shaped balloons may not be able to lift off | *Sheprical shapes hold heat better than the same amount of material in a different shape.* |

Complete table2 by listing factors that cuase or effect the rise and fall of magma. The first box has been filled in as an example.

Table 2

|  |  |
| --- | --- |
| **Magma rising** | **Effects on magma** |
| lithosphere | *More dense than magma* |
| Continental lithosphere is less dense than mantle | *Slows the ascent of magma* |
| Magma heats surrounding rocks | *Makes surrounding rocks more deformable so magma can rise* |
| Magma solidifies within crust | *Solidified magma can no longer rise* |
| Magmas along fractures | *Increasing the surface area of the magam causes it to cool more quickly* |
| Magmas lose gases and sink | *Increased density due to loss of gas cause magma to descend.* |
| Water in mantle | *Causes melting which creates magma* |

**Part A. Alignment**

A balloon rising and magma rising are analogous. That is, many elements and relationships correspond. They correspond because elements and relationships can be described by the same causal principles or effect. Table 3 lists some relevant elements of a hot air balloon rising. Complete table 3 by filling corresponding elements from magma rising listed in table 4 and the effects or role played in the balloon and magma movement. What you write in the right column may or may not be the same as you wrote in tables 1 & 2.

Table 3

|  |  |  |
| --- | --- | --- |
| **Balloon rising** | **Magma rising** | **Causes or Effects on movement of balloon/magma** |
| Gas flame | *Water in mantle* | *Causes density decrease* |
| Atmosphere surrounding balloon | *lithosphere* | *More dense than balloon/magma* |
| Atmosphere decreases in density with increased elevation | *Continental lithosphere is less dense than mantle* | *Slows the ascent of balloon/magma* |
| Limited fuel to continue heating the air in the balloon | *Magma looses heat to surrounding rocks* | *Slows ascent* |
| Air get warmer during the day | *Rising magma heats lithosphere* | *Decreases density contrast but makes it easier for the lithosphere to flow and therefore for the magma to rise* |
| When the balloon stops being heated it descends | *Magmas lose gases and sink* | *Increased density due to cooling/loss of gas cause balloon/mamga to descend.* |
| Irregular shaped balloons may not be able to lift off | *Magmas along fracures cool ans solidify* | *Sheprical shapes hold heat better than the same amount of material in a different shape.* |

Table 4

|  |
| --- |
| **Elements of magma rising** |
| *Water in mantle* |
| *lithosphere* |
| *Continental lithosphere is less dense than mantle* |
| *Magma heats surrounding rocks* |
| *Magmas along fractures* |
| *Magma solidifies within crust* |
| *Magmas lose gases and sink* |

**Part B.**

Important Alignable Differences between balloons and magma.

Making Analogies isn’t just about finding what’s similar between two domains, but also discovering and understanding important differences.

When aligning the balloons and mamga, it becomes clear that buoyancy drives the movement of both. In both cases, temperature affects buoyancy. However, there are also some different feaures that affect buoyancy. Complete table 5 with features in the balloon and maga that effect buoyancy but otherwise, do not match.

Table 5

|  |  |
| --- | --- |
| **Balloon** | **Magma** |
| *burning gas to heat balloon* | *water to cause melting* |
| *density of atmosphere limits the height to which balloon may rise* | *magma may solidify and therefore nolonger rise* |
| *balloons return to ground* | *agmas do not settle back into the mantle* |

**Part B. Evaluation Inference:**

Analogies help us make inferences. In this exercise, we hope the analogies between hot air balloons and rising magmas provide you with a better understanding of the mechanism of movement of magmas. As a test of this understanding, please answer the following question.

Here are two statements about rising magmas. Based on what you read and know about balloons, choose true or false for each and explain your choice.

1. When magmas rise close to the surface, gas bubbles in the magma may leak out fractures much like gas can leak out a hole a balloon. This may cause the magma to stop rising. T,F

*True- Gas bubbles expand within the magma decreasing its density. If these buubles leak out of the magma, it will become denser and may cease to rise.*

2. A single magma is unlikely to rise from the mantle to the surface of the lithosphere unless other magmas rise underneath it and add heat to the overlying magma. T,F

*True- As magmas rise, they lose heat to the surrounding rocks. As the surrounding rocks become hotter, less heat is lost from the magma.*

**Assessment:**

The Ring of Fire is a zone around the Pacific Ocean that marks subduction of oceanic lithosphere below other oceanic lithosphere or continental lithosphere. Explain why volcanoes are more common where oceanic lithosphere subducts under other oceanic lithosphere rather than continental lithosphere.